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THE UNAFLOW PUMPING ENGINE[1]

By D. A. Decrow

The Unaflow steam engine derives its name from the fact that the steam travels over a path into and through the steam cylinder in one direction; it does not counter-flow or return over its own path. It has sometimes been called "Unidirectional flow" but more commonly "Una-flow," but as the hyphen will ultimately disappear, the word "Unaflow" is now being used to designate this type. This paper is not intended to be highly technical, but rather to be partly historical, partly descriptive and partly anticipatory, interesting in a way perhaps, because it illustrates to a certain extent the various phases of the development of a new type.

The Unaflow engine is not particularly new in principle but its successful development as a practical and economical commercial machine is quite recent and its adaptation to reciprocating pumping engine practice new. A number of inventors during the past thirty or forty years have been attracted by the Unaflow principle but none of them has until quite recently succeeded in perfecting its development so as to make it a successful, economical and commercial production.

While he does not seem to have been the first, J. L. Todd is possibly the most prominent of the early inventors who attempted to apply the Unaflow principle to the steam engine. His first patent was a British patent issued in 1885. He was not able to make it a mechanical or commercial success, though he spent many years and much money in the effort. About 1895 he apparently gave up trying to make a success of the pure Unaflow and adopted the "Dual" or double-exhaust engine, which was a combination of the Unaflow and counter-flow type; he, however, did not appear to have followed the right lines in the development of his Dual exhaust engine to make for unqualified success, for it has not come into general use.

After these early and on the whole unsuccessful attempts, interest in the Unaflow engine died out for a considerable period, but quite

[1] Read before the Buffalo convention June 10, 1919.

recently inventors have been attracted to it and much experimental work has been done; Prof. J. Stumpf took it up actively, overcame previous difficulties and to him undoubtedly falls the honor of making the first practical and commercially successful application of its principles to modern steam engine practice; his inventions and adaptations have been generally recognized. During the period directly previous to the beginning of the late war, many of these Unaflow steam engines were constructed in England and on the continent

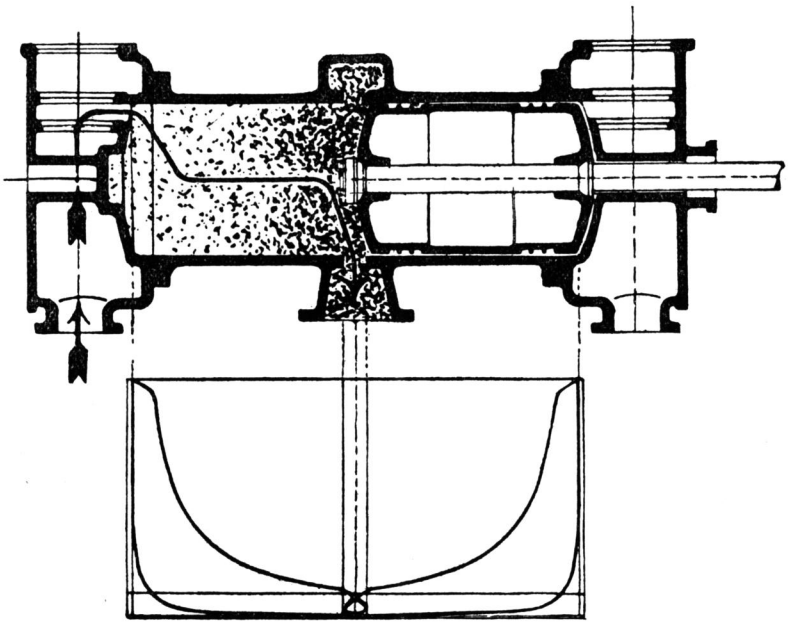

FIG. 1. TYPICAL UNAFLOW STEAM CYLINDER AND INDICATOR CARDS

for various kinds of power service, but in the United States it has not until recently been developed and adapted for power units in conformity with American practice, activity along these lines having been restricted greatly by reason of war requirements on the engineering and manufacturing resources of the country. The war is now over, rapid progress is being made in its development, many power units have been and are being installed and a number are in successful operation.

Broadly speaking the general principle of the Unaflow reciprocating steam engine is that of utilizing the heat energy of the steam in

the cylinder during the period of its admission, expansion and flow in one direction, the expanded steam being released or exhausted through ports or openings uncovered by the travel of the cylinder piston at that period of its stroke most remote from the point of admission; the comparatively cold expanded or exhausted steam does not counter-flow and pass through ports at or near the admission or hot end of the cylinder.

In the accompanying sketch of a typical "Unaflow" engine steam cylinder and indicator cards, the piston is at one end of the stroke with the exhaust ports uncovered. The arrow indicates the path of the steam through the cylinder. The indicator diagram shows that steam is admitted into the cylinder for only a very minor portion of the stroke and is then cut-off, the work performed during the remainder of the stroke being due to the expansion of the steam after the inlet valve closes. The exhaust opens when the piston, which is much longer than the ordinary engine steam piston, travels past and uncovers the exhaust ports midway between the two ends of the cylinder.

Beginning with the steam in the cylinder there is practically no change of temperature until the point of cut-off. After cut-off, expansion takes place with a consequent drop in temperature and at this time condensation begins, due to the changing of heat into work. As the cylinder head is jacketed with high steam no condensation takes place on the walls of the head, but the condensation is on the wall of the piston, which is comparatively cool, and adjacent thereto, so that at the end of the stroke when the piston uncovers the exhaust ports the moisture of condensation is mostly at the exhaust end of the cylinder, and as the steam expanding away from the cylinder head rushes out through the exhaust port, it carries the moisture with it.

At this time there is a sudden drop of temperature in the cylinder due to the sudden drop of pressure, but as the inlet end of the cylinder is dry it does not lose its temperature, the flow of heat from a dry surface being slow and there is not sufficient time for any perceptible drop in temperature of these dry walls. The exhaust port is covered by the piston on the return stroke, trapping in the cylinder comparatively dry steam partially superheated; as the walls of the cylinders have retained their heat, the heat of compression is not absorbed either by moisture or by cold walls, as in the case of a counterflow engine, and the steam remaining in the clearance is heated by compression to a temperature above the temperature of the initial steam;

when the valve is opened to start the next stroke the live steam rushing in goes into a clearance space in which the steam entrapped is hotter than the entering steam, hence no initial condensation. Owing to the complete removal of all of the mixture of each stroke, the well known heat losses caused by the presence of water in counterflow engines are avoided.

Eliminating initial condensation permits an economical high ratio of expansion in one cylinder. For normal working conditions about sixteen expansions have been found to give best results.

It is also evident that with the use of exhaust ports in the cylinder instead of the usual exhaust valves, leakage losses at the exhaust valves and the losses due to all of the added clearance space and surfaces which necesarily follow from the use of a special exhaust valve, are eliminated. It has been found practical to reduce the clearance space in condensing engines to 3 per cent of the swept volume of the piston.

Some of our manufacturers of Unaflow steam power engines have guaranteed as low as 10 pounds of steam per indicated horse power per hour, and some of the tests of European built engines have shown well under 9 pounds.

Taking into consideration its simplicity, for with a single cylinder substantially the same economy is obtained as with the best types of compound or triple expansion steam engines, the Unaflow engine marks a distinct step in advance of the other types of reciprocating engines. These advantageous features have attracted attention to its desirability as a motive power for reciprocating pumping engines.

To develop a pump that could be combined with and utilize the advantageous features of the Unaflow engine requires that due consideration be given to proper channels for passing the desired amount of water to and through the pump with the least practicable amount of deflection and disturbance of the flow. This can best be attained by incorporating the Unaflow principle in so far as it will apply to a pump. The pump should be provided with passages ample and direct so there will be no reversal of flow, with plungers properly proportioned and formed to cause a minimum disturbance, with suitable suction and discharge air chambers properly located, with pump valves that will deflect the direction of flow as little as possible, that will operate quickly and quietly at all pressures and economic speeds of the engine, and furthermore, that will be durable and lasting in operation.

One of our pumping engine manufacturers has designed, constructed, erected and will operate in the Porter Avenue water works pumping station of the City of Buffalo, especially for the inspection and information of the members of this convention, a complete Unaflow high-duty condensing pumping engine of about 3,000,000 gallons daily capacity.

It was intended at the time it was decided to construct this pumping unit, to not only have it ready for operation, but also to have completed a series of tests of its efficiency with the results properly tabulated; but war and other work was so pressing it was not found practicable to do this latter. These tests will be made later and the results published; they will be comprehensive and thorough, both as to normal working conditions, and as to variations in capacities and pressures, in order that accurate economy curves may be constructed. It is anticipated that the tests will show a very high duty and that a flat economy curve will be obtained. The installation is shown in figure 2.

This engine is of the horizontal extended type (so called), having one steam cylinder and one double acting plunger pump; its normal working water pressure is 100 pounds per square inch; the suction left is approximately 15 feet plus the friction in about 60 feet of suction pipe; these are not particularly favorable working conditions, rather the reverse. The engine may be duplex or triplex which would double or triple its capacity, it also may be of the opposed or interposed types, horizontal or vertical. The normal steam pressure at the Porter Avenue Station is 235 pounds per square inch with 100° F. superheat.[2]

The outstanding features of the Unaflow pumping engine are: Simplicity of construction; low cost of production as compared with compound and triple expansion reciprocating pumping engines; high duty or economy in the use of steam not only in the large but also in the small units. For instance, the 3,000,000 gallon unit above mentioned is expected to develop a duty of 180,000,000 foot pounds per 1000 pounds of steam, and to maintain this duty more nearly under variable loads than any other known type.

[2] In the brief discussion of the paper the author stated that the valve lift was 0.3 inch and that the velocity of flow through the valves was 3 feet per second when the pump was delivering 3,000,000 gallons. The operation of the pump at various speeds was witnessed by the members of the Association during the convention.—*Editor.*

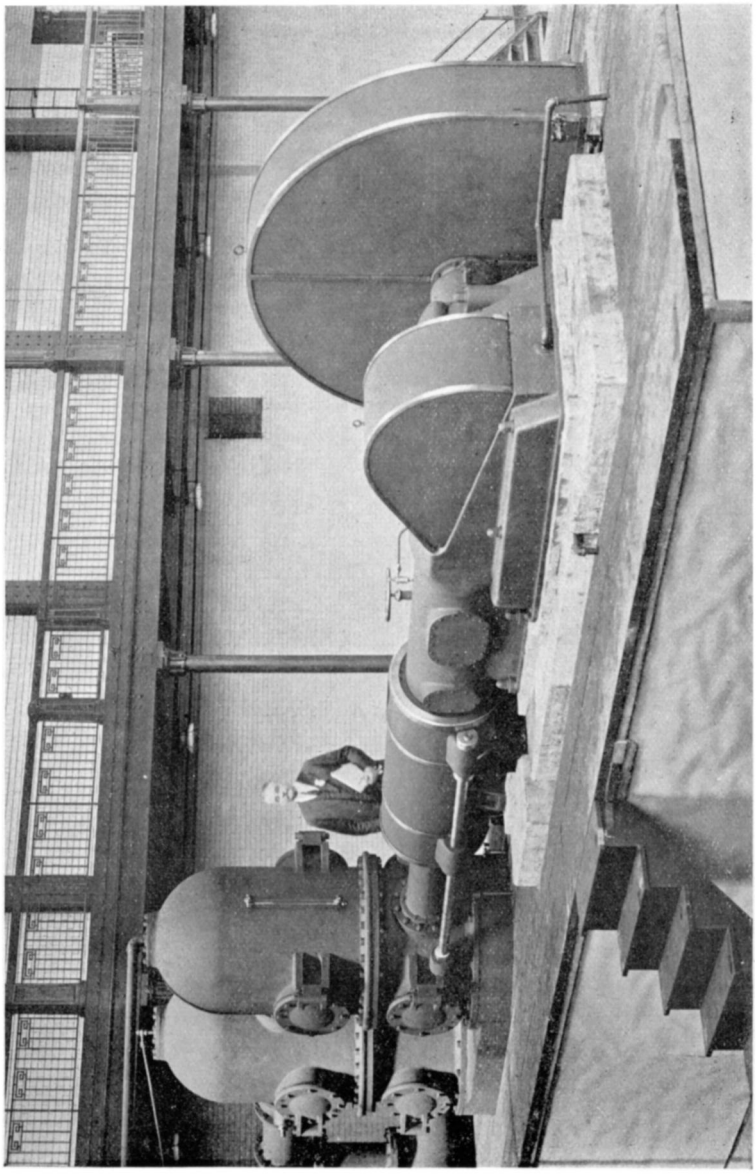

FIG. 2. A UNAFLOW HIGH-DUTY CONDENSING PUMPING ENGINE